Environmental Effects of Dredging Technical Notes

Dredged Material-Filled Geotextile Containers

Purpose

This technical note describes the use of geotextile containers, hydraulically and mechanically filled with a variety of dredged material types, to address difficult dike construction problems and disposal of clean and contaminated dredged material. Information is also given on design and construction, potential applications, and example projects.

Background

Woven and nonwoven permeable and impermeable synthetic fabrics have been used for the past 30 years for various types of containers, such as sandbags, geotextile tubes, and geotextile containers. In recent years, design and construction of geotextile containers filled with dredged material has gained popularity. Geotextile containers filled with granular dredged material have been successfully used in constructing groins, but filling these containers with fine-grained maintenance dredged material and contaminated dredged material has been very limited.

Beneficial uses of fine-grained dredged material are limited because of the material's high water content, low strength, and low angle of repose, as well as managers' lack of control with regard to where the material will migrate. Containment of dredged material in geotextile tubes, bags, or simply large containers (filled in place or filled in large split hull, bottom dump hopper barges and disposed below water) has helped solve several difficult construction problems. Numerous examples can be given of projects that could not have been completed without the use of geotextile containment systems. Among these are

Note: The contents of this technical note are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

dike construction using long continuous tubes in wetlands, subdivision and perimeter dikes in dredged material disposal areas, underwater stability berms, containment of contaminated materials, island construction, barrier island, breach repair, placement of fill in surf conditions, and thalweg and structural scour protection.

Additional Information

For additional information, contact the authors, Dr. Jack Fowler, (601) 634-2703; Mr. C. Joel Sprague, Greenville, SC; and Mr. Dana Toups, Nicolon Corporation, Atlanta, GA (Corps of Engineers' Construction Productivity Advancement Research Program partner) (800-548-7008); and or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler, (601) 634-3624.

Introduction

Dredged material-filled geotextile containers offer the advantages of simplicity in placement and constructability, cost effectiveness, minimal impact on the environment, and confidence in containment. In addition, geotextile containers filled with fine-grained dredged material provide the opportunity for beneficial use, storage, and subsequent consolidation of this material in dike construction and wetland creation. Tests with nonwoven liners have shown that no particulates escape from the geocontainers. These containers have demonstrated 100-percent containment of fine-grained dredged material.

Vegetation growth through these containers is very promising, with natural propagation taking place after the containers are filled and the fine-grained dredged material consolidates.

The Waterways Experiment Station (WES) recently filled four tubes (approximately 150 m long) with fine-grained maintenance dredged material, for potential use by the Corps of Engineers' Mobile District for dike construction and wetland creation at Gaillard Island Dredged Material Disposal Island, Mobile, AL. Pressure measured in the tubes ranged from about 4 to 5 psi (28 to 34 kPa), and strains were less than 3 percent.

WES also recently instrumented geobags and geocontainers with pressure cells and strain gauges in a sedimentation control project on the Mississippi River at Red Eye Crossing near Baton Rouge, LA. This project consisted of six underwater sedimentation control dikes (between approximately 180 and 425 m long, and 9 m high). Over 40,000 bags and about 700 containers were dropped in 18-m-deep water, with a current of 4 fps (1.2 m/sec), without failure or placement inaccuracy in the dike cross section.

It was discovered that the terminal velocity of the bags and containers was achieved in less than 0.25 sec of free fall. A terminal drop velocity between 3.5 and 4.5 m/sec was observed. Maximum strains were recorded not upon impact with the river bottom, but during the time the split bottom dump scow

was being opened. It required about 60 sec for the containers to finally free fall from the scow. Maximum peak strains occurred for a period of approximately 5 to 6 sec prior to final release and free fall from the split hull barge. Eight to 12 percent maximum peak strains were recorded during release, and only 3 to 4 percent strains were recorded upon impact with the bottom. A more detailed report is currently being prepared at WES.

In recent years, various types of containers have been used. Nicolon Corporation copyrighted the name for GeoTubes and GeoContainers. GeoTubes have been used extensively on the northern shores of the Netherlands for dike construction, with fine-grained dredged sands pumped to form a barrier dike, for subsequent hydraulic fill behind the dike. GeoContainers, which are dumped either from dumptrucks or split hull bottom dump hopper scows, have been used in the Netherlands for construction of underwater berms and thalweg scour protection. GeoContainers can be mechanically or hydraulically filled inside bottom dump hopper scows, moored into place, and dumped. Design concepts for material tensile strength, seaming requirements, and properties with regard to creep, abrasion, ultraviolet protection, tear, and puncture are presently being documented under the Construction Productivity Advancement Research (CPAR) Program, for which Nicolon Corporation is the Corps' industrial partner.

Dredged material-filled tubes have been used as containment dikes in Brazil and France (Bogossian and others 1982, Perrier 1986), and more recently in the Netherlands and Germany for river "training" structures on the Waal and Old Meuse Rivers and as shoreline protection at Leybucht on the North Sea.

Experimentation with dredged material-filled fabric tubes was first tried in Brazil in the early 1980s with a variety of fill material types (clay balls, shells, and fine-grained sand) for land reclamation for housing. This technique was also used in France to isolate and contain runoff from a contaminated area.

In the Netherlands, ACZ Marine Contractors BV developed dredged material-filled fabric containers for constructing underwater groins for sedimentation control. A prefabricated steel cradle was used to position prefilled tubes in place in stacks without dropping them from the barge. The special cradle bucket was used to place over 500 tubes during construction of 11 groins.

In another Dutch application, the Public Works Department of the Netherlands chose 233 mechanically filled fabric containers (GeoContainers) dropped from a split barge to fill an eroded area of river bottom. Another Dutch contractor, Vanden Herik Kust-en Oeverwerken BV, with the help of Nicolon BV, developed this system.

GeoTubes were successfully filled with a hydraulic suction dredge for dike construction for the project Leybucht on the North Sea in Germany in 1988. The continuous GeoTubes provided a temporary barrier from currents and waves from the North Sea until material was placed behind the containment and wave armor protection was emplaced.

Several GeoTube and GeoContainer projects have been designed and constructed in the United States. The performance of these projects is being documented under the CPAR Program so that improved design and construction methods can be recommended. More recently, dredged material-filled tubes have been used in other U.S. projects such as those listed below.

- Shoreline protection groins, Destin, FL (City of Destin).
- Dredge disposal containment, Mobile, AL (U.S. Army Engineer District, Mobile).
- Two shoreline protection/breakwater/disposal containment projects, Galveston, TX (U.S. Army Engineer District, Galveston).
- Shoreline protection of Amelia Island, Florida.
- Beach breakwater protection between groins, Avalon, NJ.
- Erosion protection, Chesapeake Bay (U.S. Army Engineer District, Baltimore).
- Geobags and geocontainers for sedimentation control at Red Eye Crossing, Baton Rouge, LA (U.S. Army Engineer District, New Orleans).
- Bull Island breached dike, Charleston, SC (U.S. Army Engineer District, Charleston).

Geotextile Container Design and Construction

GeoTube and GeoContainer systems are generally tubular in shape, with the ends taking on the shape of a pillow when filled with dredged material (Figure 1). About 85 to 95 percent of the fine-grained dredged material passes a 74-micron or 200 sieve size. Therefore, the fabric must be designed to retain this size soil particle. Sandy material generally has a relative density of medium dense, whereas fine-grained silts and clays are very soft with a water content above their liquid limit.

The simplest GeoTube is two sheets of geotextile sewn along the edges, with inlets and outlets sewn about every 33 m, depending on the sedimentation characteristics and angle of repose of the dredged materials. The tube is made with fabric widths of 3.8 to 5 m running in the longitudinal direction of the tube. Normally, the tube is wrapped on a steel pipe for transport and handling.

Length of a GeoTube is limited only by the weight of the geotextile material that can be handled in the field. Wider GeoTubes can be folded and placed on pallets, and then unfolded and dragged into place at the construction site. These wider GeoTubes are made up of several sheets of fabric and serve as miniature dredged material disposal areas.

Permeable and impermeable liners have been used inside geotextile containers to limit the amount of material. Impermeable liners also increase the velocity in the containers for material transport over long distances inside the tubes. Polypropylene and polyester yarns are used to construct the fabrics, which are

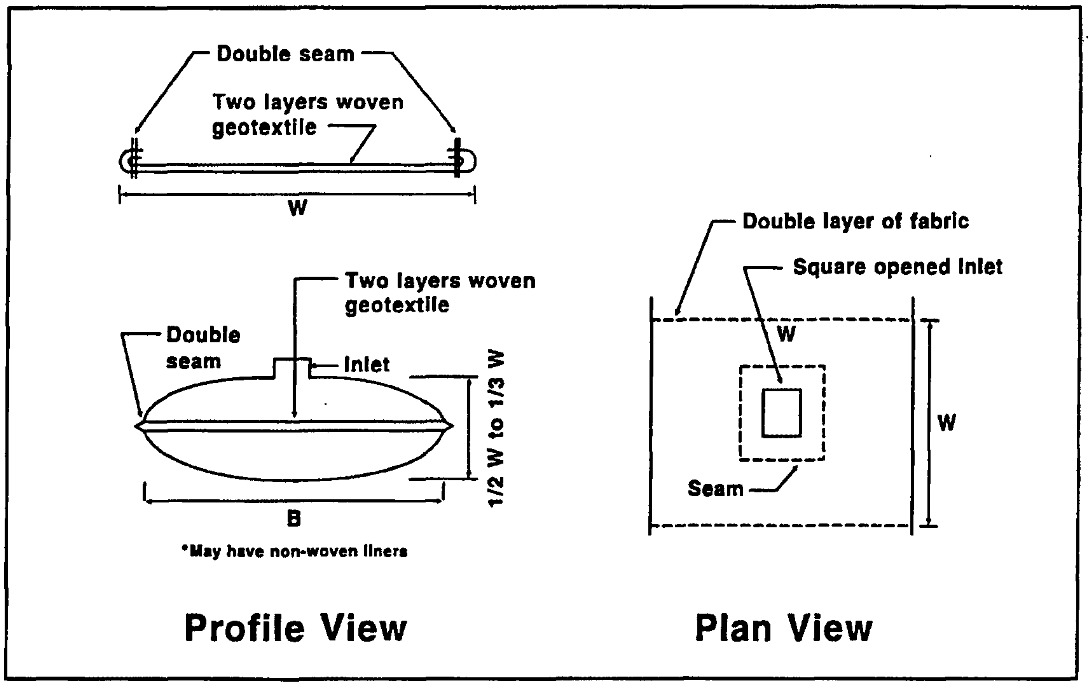

Figure 1. GeoTube construction

sewn to form the containers. The seam strength is normally the weakest link in the design and, depending on the seaming technique specified, this value may be only 50 to 75 percent of the fabric's ultimate strength.

The inlet/outlet "sock" diameter is somewhat larger than the filling/discharge pipe (Figure 2). The inlet/outlet fabric is more open, to serve as a pressure relief point and allow decantation water to drain after consolidation of the dredged materials. The maximum filling pressure at the inlet point should not exceed about one third atmosphere.

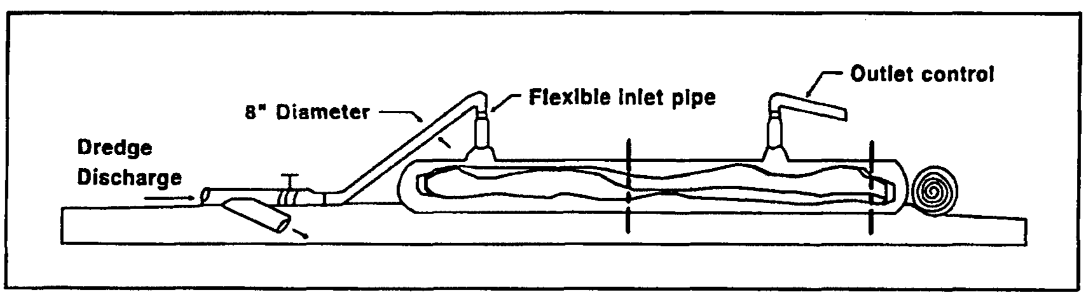

Figure 2. Tube being filled

Dredged material-filled fabric tubes are constructed by hydraulic filling of the envelope with a water-soil mixture using a cutter suction pipeline dredge. The dredged material-filled fabric tubes can be prefilled and placed using a "cradle" bucket on a barge-mounted crane, or they can be installed using a continuous position-and-fill procedure.

The geotextile fabric used to construct the container system is designed to

- Contain sufficient permeability to relieve excess water pressure.
- Retain the dredged material (nonwoven liners retain virtually 100 percent of the fine-grained dredged material).
- Resist the pressures of filling and the active loads without seam or fabric rupture.
- Resist mechanical abrasion forces during filling operations.
- Survive construction abuse during placement.
- Resist puncture and tearing.
- Resist ultraviolet light.

These pillow-shaped tubes will achieve a profile of 70 to 80 percent of the theoretical circular diameter or a height equal to about one third to one half the flat width of the container before it is filled (Figure 1).

At Gaillard Island, in situ dredged material densities of 1,200 to 1,300 g/L have been hydraulically pumped directly into these tubes from the navigation channel. After 4 to 6 weeks of drainage, the dredged material in the tubes increased in density to about 1,400 to 1,500 g/L, and the tubes reduced to about 50 percent their original height. The tubes were then filled a second time.

As the technology associated with manufacturing, deploying, and filling dredged material-filled fabric tubes has been demonstrated, additional innovative applications have been proposed. Generally, these can be categorized as river, estuary, and shoreline/coastal applications, as described below.

River Applications

Rivers commonly need to be maintained, trained, or adapted to accomplish or improve their desired function. Further, the adjacent parts have to be protected against inundation during high water levels. A number of typical solutions are available to direct currents and to resist scour, including dams, dikes, groins, dredging, and bottom and bank armor.

Dredged material-filled fabric tubes, because of their simplicity, flexibility, and resulting stability against erosive forces, provide an innovative, cost-effective alternative to the traditional techniques used to construct typical current-guiding and scour-preventing structures in the river.

Problems associated with underwater construction and bag/container placement have been demonstrated at Red Eye Crossing, Baton Rouge, LA, to be manageable.

Current-Guiding Structures

Usually, current-guiding structures are constructed with natural rock. As an alternative, a structure can be built up by one or more dredged material-filled

fabric tubes. By varying size, number, and composition of the tube units, any structure can be produced.

Current-guiding structures, including revetments, groins, and longitudinal dikes, are used to prevent localized erosion, to regulate the riverbed to concentrate the river into one channel, and to normalize the riverbed to fix the horizontal profile.

As shown in Figure 3, regulation of the river over an extended length is achieved by a combination of these structures. Views and cross sections of individual structures are presented as Figures 4 and 5.

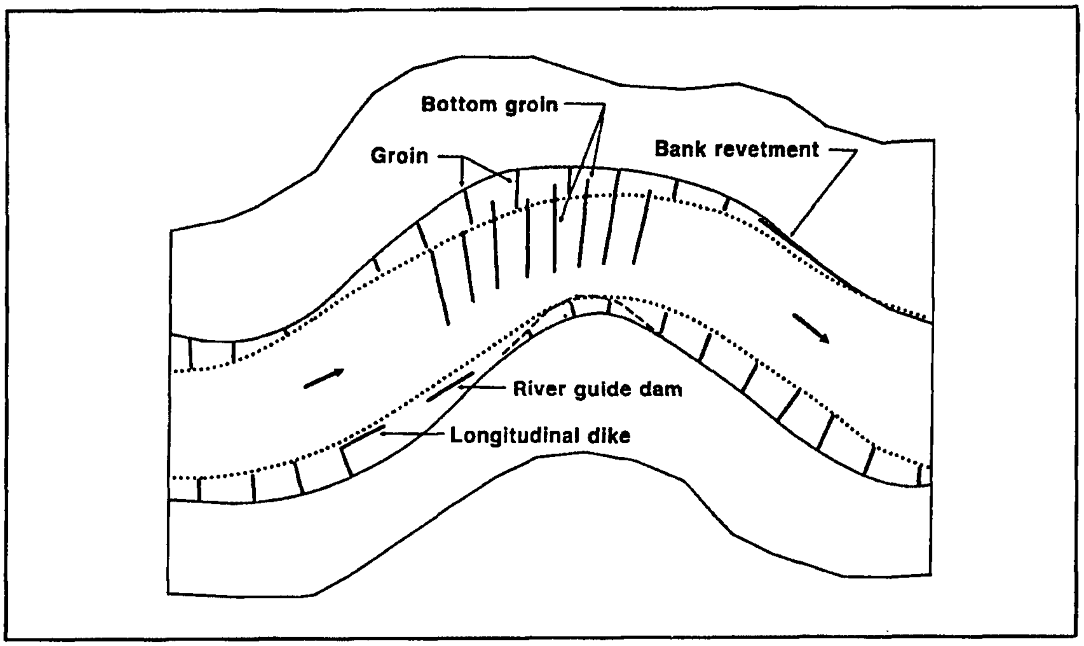

Figure 3. Combination of river regulation structures

Scour-Preventing Structures

Scour can be prevented by securing the riverbed with an armoring system. Usually, this bottom protection consists of a primary armor rock layer with one or more filter layers underneath to prevent sediment from passing through the rock protection. By filling in and covering a depression in the riverbed with dredged material-filled fabric tubes, the same result can be achieved. The tubes have to be positioned closely together to prevent current access and resulting sediment passage.

Estuary Applications

An estuary is that general area at the mouth of a river into which the tide flows. Extensive wetlands (marshes and swamps) are characteristic of estuaries and are frequently threatened by erosion and subsequent saltwater intrusion.

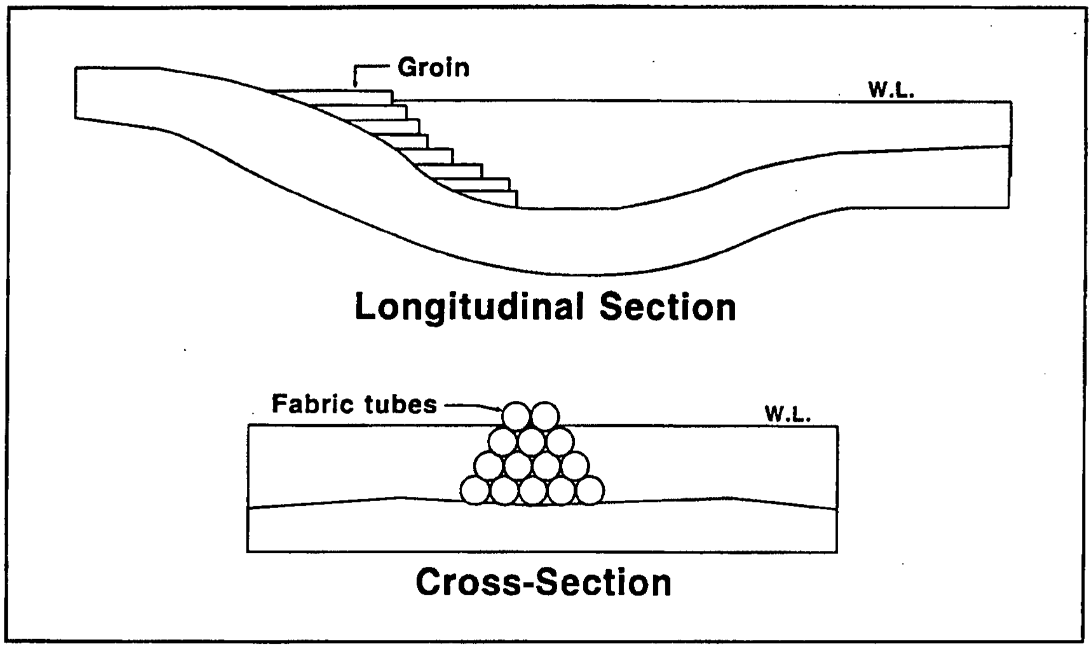

Figure 4. Groin (current-guiding structure)

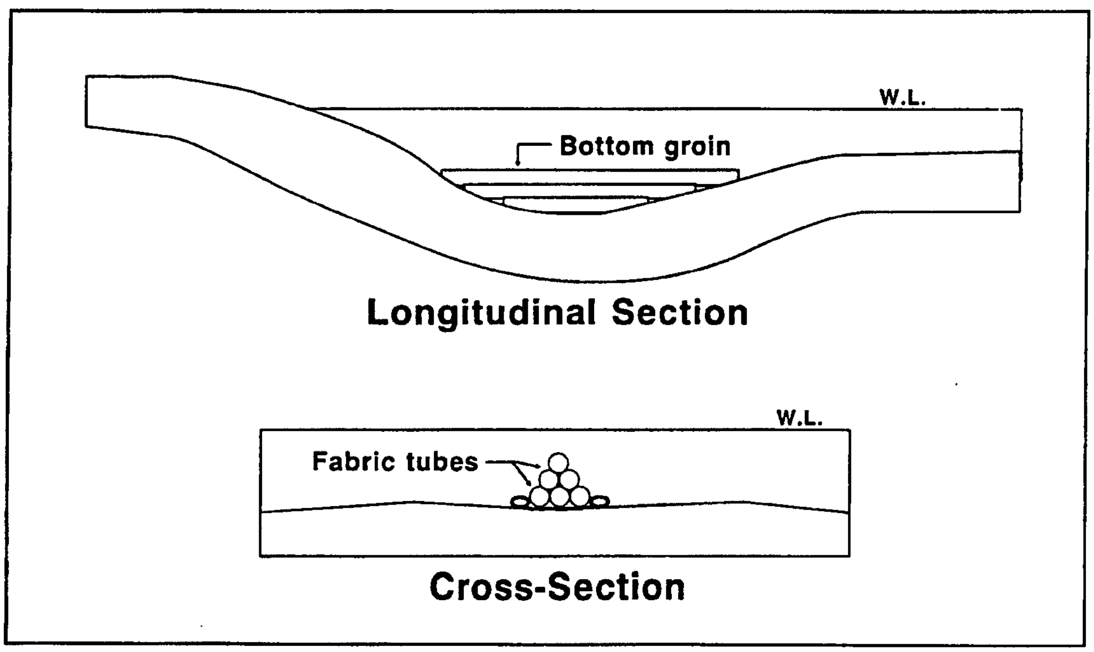

Figure 5. Bottom groin (current-guiding structure)

Efforts to protect, reclaim, or increase these areas can be enhanced by using longitudinal dike structures where traditional construction techniques are ill-suited or cost-prohibitive. Dredged material can be used to fill the tubes, as well as to fill in behind the tubes to reclaim or increase wetlands.

Additionally, it has recently been recognized that the dredging of harbors, channels, and other navigable waterways sometimes produces dredged material that may have an unacceptably high amount of toxic elements. Hydraulic dredging of this material creates a need for retainment dikes or berms to prevent this slurry from running back to the environment, while providing a wide settling basin. If necessary, these basins can be enclosed and covered with impermeable layers to isolate the contaminants. These basins can extend underwater as well as on shore. Figure 6 illustrates the application of dredged material-filled fabric tubes for construction of a containment dike.

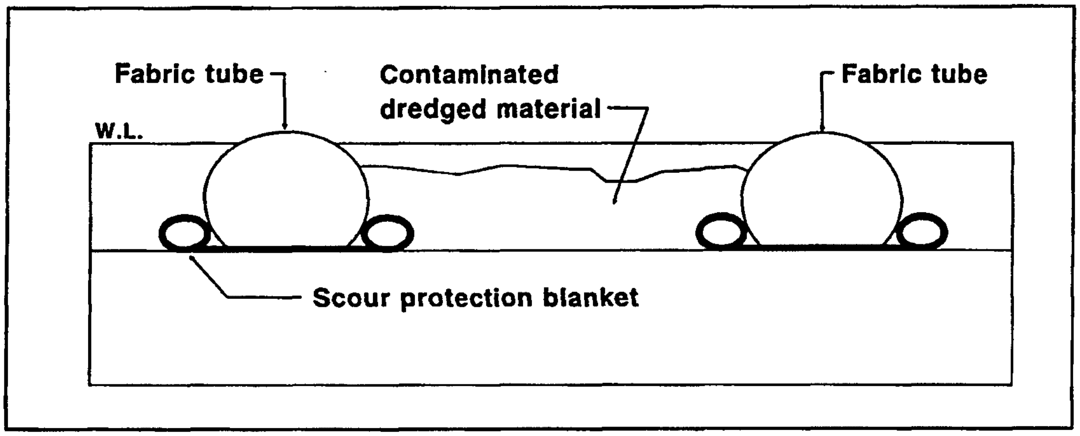

Figure 6. Containment dike

Coastal Applications

Beach nourishment projects often incorporate groins, breakwaters, or sill structures as effective tools for trapping littoral drifting sediments, which stabilizes the shoreline. Because of their flexibility, structural integrity, and relatively large mass, dredged material-filled fabric tubes are very suitable for use as groins, breakwaters, or sills. They can also be used as containment dikes for reclamation of land or creation of artificial islands in the coastal environment as they are in estuaries. Also, gullies, caused by tidal currents, can be interrupted or filled using dredged material-filled fabric tubes.

Groins

Where there is an abundant supply of littoral drift, the function of a groin is to build or widen a beach by trapping the sediment movement along the shore. Moreover, properly designed groins will reduce the longshore transport of sediment. This is achieved by reorienting the compartmented shoreline, so that it will be in closer equilibrium to the predominant wave direction. An example groin is shown in Figure 7.

Figure 7. Coastal groins

Offshore Breakwaters

Offshore breakwaters can be used to reduce the force and vary the direction of waves striking the shore, thereby reducing shore erosion without harming the recreational aspects of the beach. Breakwaters are located away from the shore, and can either be submerged or the crest can be elevated above sea level during all tides. Breakwaters tend to reduce littoral transport along the shoreline side of the structure. Figure 8 shows a typical plan and cross section for a detached breakwater system.

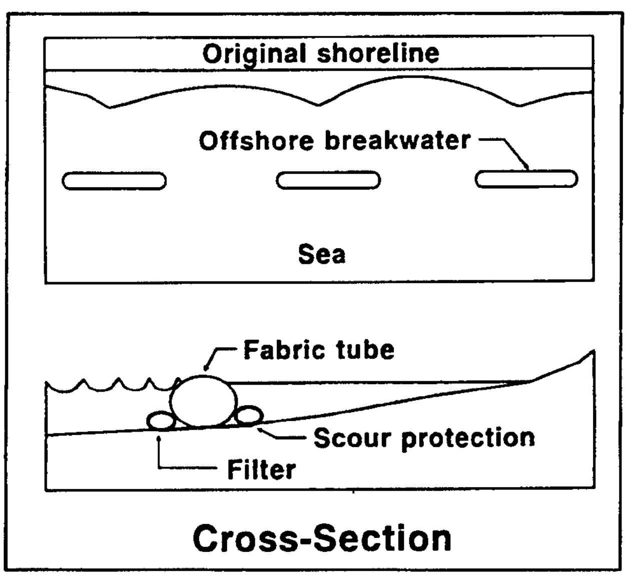

Figure 8. Offshore breakwater

Sill Structure

A wide protective (perched) beach or shallow offshore can be retained by means of terracing with the construction of beach retaining sills. Wave energy is dissipated while propagating over this shallow region by

breaking and bottom friction. Hence, waves have a reduced erosive effect upon the shoreline. Figure 9 demonstrates the use of dredged material-filled fabric tubes as sill structures.

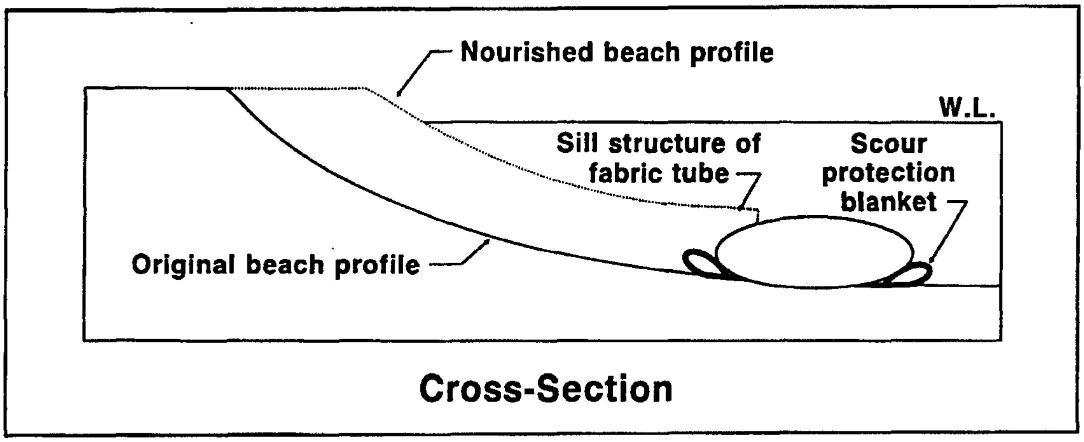

Figure 9. Sill structure

Sand Dunes

GeoTubes are being used inside of sand dunes along coastal areas where hurricane storms continually destroy the dunes (Figure 10). Placement of GeoTubes within the dunes will reduce maintenance cost in dune repair and replacement.

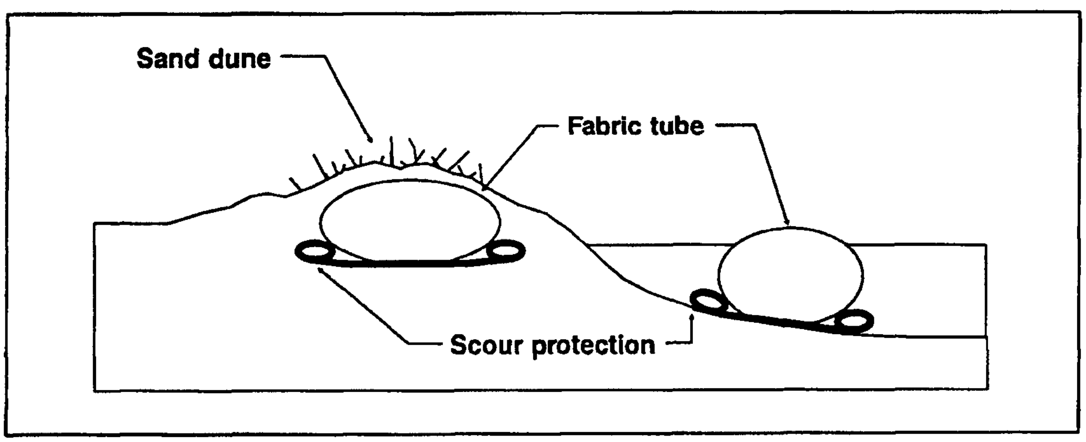

Figure 10. Sand dune

Land Reclamation

Construction of artificial islands with dredged material-filled fabric tube systems represents an additional use for both underwater construction and shore protection techniques. Advantages include the reduction of required fill materials, speed of construction, and relatively low costs. Removal, which is often required for temporary energy exploration structures, is also easily accomplished.

Gully Repair

Gullies are caused by tidal currents. In the vicinity of coastal structures, gullies can cause geotechnical instability of the structures or provide a breach point from which the structure progressively erodes. Dredged material-filled fabric tubes can be used to fill in or interrupt gullies or breaches.

Case Histories

Bull Island provides a protected breeding habitat for wildlife in the Cape Romain National Wildlife Refuge off the coast of South Carolina. The island, which is accessible only by boat, is a favorite of scientists and tourists alike. In September 1990, Hurricane Hugo ripped through this coastal area, causing significant damage to the dunes and dikes protecting the island's freshwater habitat. Because of limited access, the Corps of Engineers was faced with repairing the main dike breach (66 m wide, 5 m deep) using limited equipment and onsite materials. Large sandbags, filled onsite and dumped directly into the breach, were used to repair the breach. This proved to be a relatively quick, cost-effective method and demonstrated the feasibility of using large sandbags as erosion-resistant construction units.

Old Pass Lagoon leads into Destin Harbor, Florida, and provides the only passage for boat traffic. After dredging was done in 1988, and again in February 1991, it was evident that accelerated erosion was taking place. Responding to the city of Destin's request for assistance, the Corps developed an innovative sand "backpass" system using a portable dredge system and dredged material-filled fabric tubes to clean sand out of the Lagoon and retain it on Norriego Point. To date, the GeoTube groins/sand backpass system is functioning as desired.

Planned Projects

Additional applications of dredged material-filled fabric tubes are planned on the Mississippi River such as those that have been constructed at Red Eye Crossing (dike construction using combinations of GeoTubes and GeoContainers); Peoria Lake (Illinois) Enhancement Program (GeoTube used in place of dikes constructed by large clamshell bucket operation); Chain-O-Lakes, Illinois (GeoTubes used to construct two demonstration wetlands); Cleveland, OH (Buffalo District) dredged material containment disposal area (dike construction using GeoTube filled with fine-grained maintenance materials; and Galveston District barrier island replacement project (using approximately 350 m of GeoTubes). The Baltimore District is planning three 1,000- to 1,200-ft-long GeoTubes and thirty-six 200-ft-long tubes for erosion control in the Chesapeake Bay.

Research efforts to contain contaminated dredged material for open-water disposal using a combination of woven and nonwoven liners are planned. Preliminary testing indicates that the fine-grained dredged material solids can be retained by the fabric liner.

In an effort supervised by the Los Angeles District, about 150,000 cu yd of contaminated dredged material from Marina Del Rey will be placed with split hull scows using 3,000-cu yd containers. The New York District and New York Port Authority are also planning demonstrations to contain contaminated dredged material with ocean placement using GeoContainers (Figures 11 and 12).

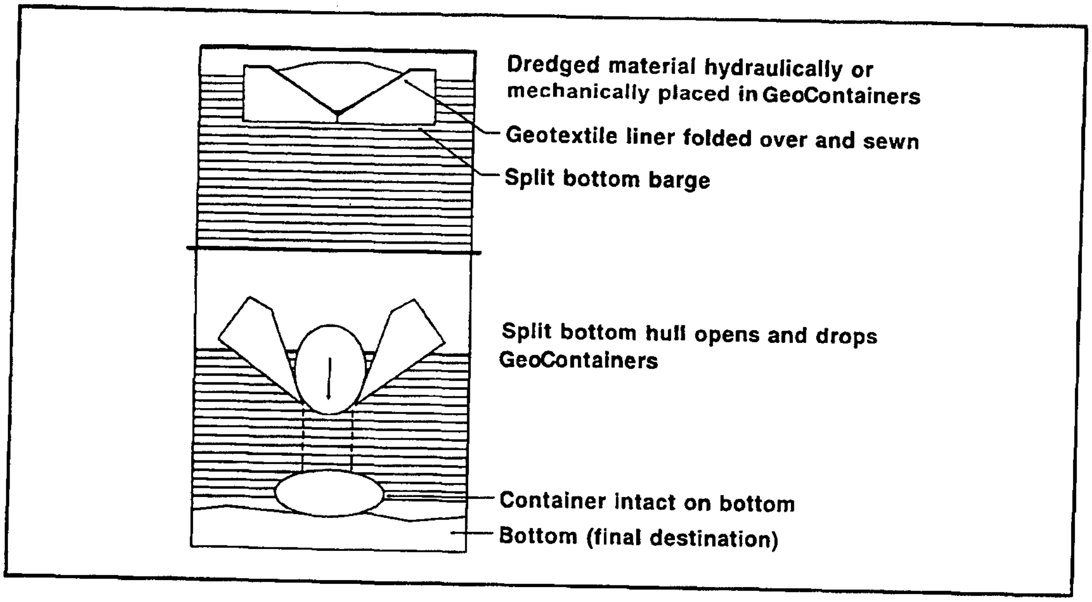

Figure 11. Design for placement of GeoContainers in the ocean

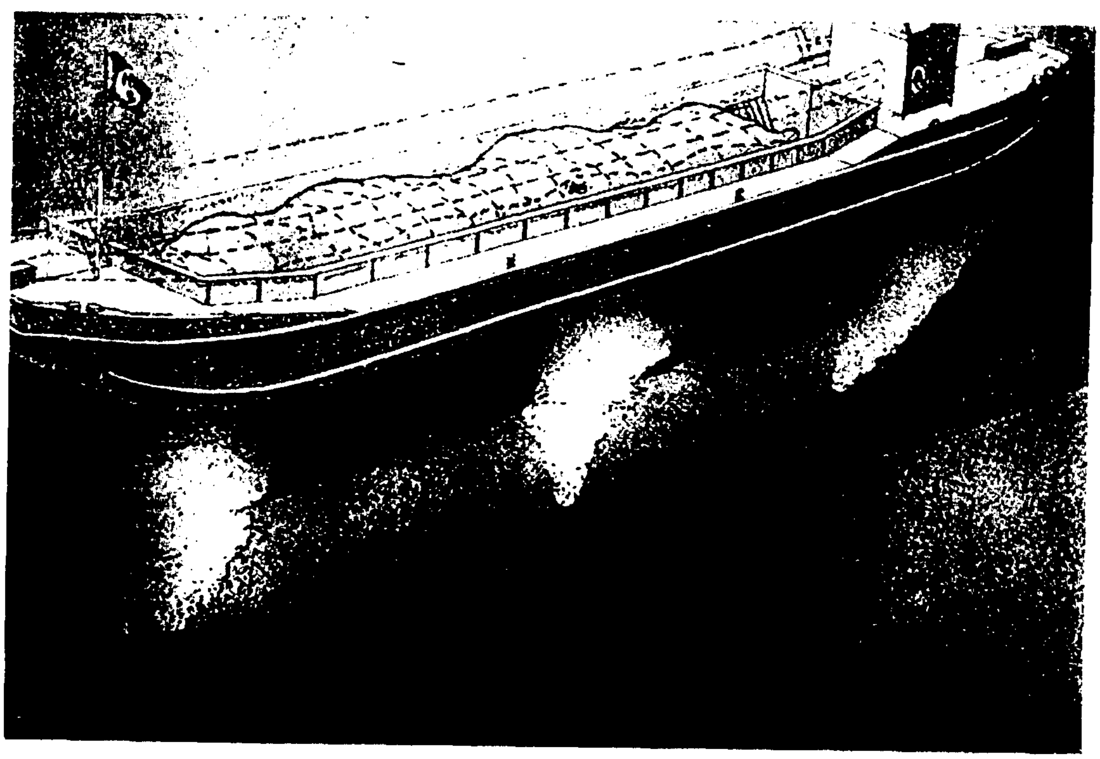

Figure 12. Split hull scow is used to place GeoContainers

References

Bogossian, F., Smith, R. T., Vertematti, J. C., and Yazbek, O. 1982. "Continuous Retaining Dikes by Means of Geotextiles," *Second International Conference on Geotextiles,* Las Vegas, NV, pp 211-216.

Perrier, H. 1986. "Use of Soil-Filled Synthetic Pillows for Erosion Protection," *Third International Conference on Geotextiles,* Vienna, Austria, pp 1115-1119.

INTERNET DOCUMENT INFORMATION FORM

A . Report Title: DREDGED MATERIAL-FILLED GEOTEXTILE CONTAINERS

B. DATE Report Downloaded From the Internet: 08/15/00

C. Report's Point of Contact: (Name, Organization, Address, Office Symbol, & Ph #):

US Army Engineer Waterways Experiment Station
Environmental Laboratory
PO Box 631
Vicksburg, Mississippi 39181-0631

D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

F. The foregoing information was compiled and provided by:
DTIC-OCA, Initials: __LF__ Preparation Date 08/21/00

The foregoing information should exactly correspond to the Title, Report Number, and the Date on the accompanying report document. If there are mismatches, or other questions, contact the above OCA Representative for resolution.